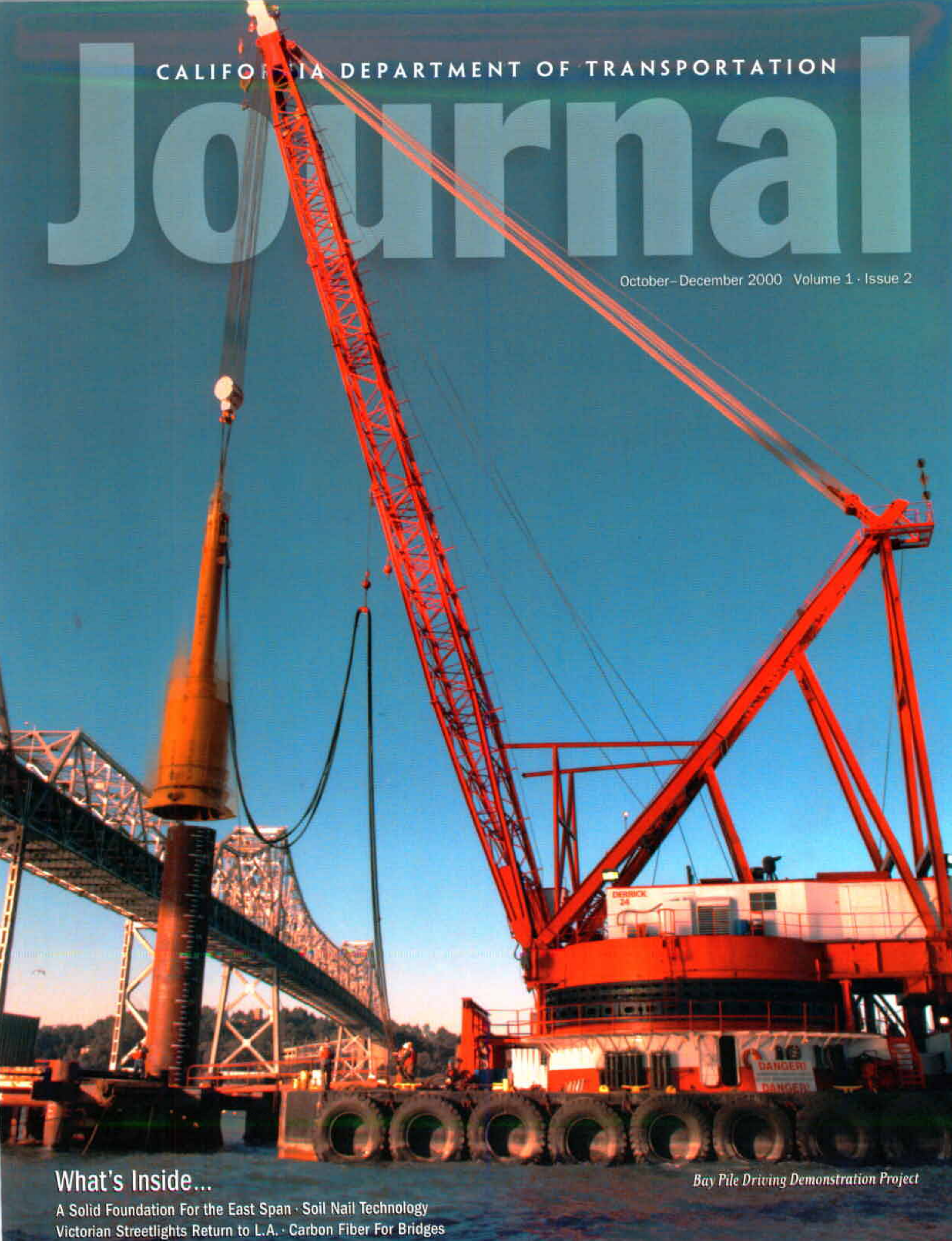
CALIFORNIA DEPARTMENT OF TRANSPORTATION

Journal

October–December 2000 Volume 1 · Issue 2



Bay Pile Driving Demonstration Project

What's Inside...

A Letter to Readers

I am extremely grateful to the dedicated men and women of our agency for their professional contribution to the safety of California's motorists. The departments within the Business, Transportation and Housing Agency comprise the Governor's principal transportation regulatory and enforcement organizations. By combining their resources, we are making driving safer, as evidenced by the fact that the number of fatalities per miles traveled is now the lowest in the state's history.

As Secretary for Transportation, I am committed to having the best traffic safety programs possible, including anti-DUI, bicycle and pedestrian safety, occupant protection, police traffic services, roadway safety and emergency medical services. These programs and so many others are helping California achieve its traffic safety successes, such as having the highest seat belt compliance rate in the nation.

Maria Contreras-Sweet

I have a charge from Governor Gray Davis to improve safety on California's roadways. That means relieving traffic congestion, thus affording people more quality time for work and family life. We all enjoy getting home quickly and safely after a hard day's work.

One of our shared goals is to alleviate traffic congestion by stopping unsafe driving behaviors that contribute to accidents. Through funding for more law enforcement personnel and equipment, emergency response vehicles and public education, we will make our roads even safer. We are also excited about the new partnerships being established with community-based organizations in California. This innovation will expand our outreach enormously. The Governor recently awarded $11.8 million to local community-based organizations to promote traffic safety programs.

Traffic safety is everyone's business. Governor Davis and I look forward to working with all of you to improve the quality of life for all Californians.

Maria Contreras - Sweet

CALIFORNIA DEPARTMENT OF TRANSPORTATION

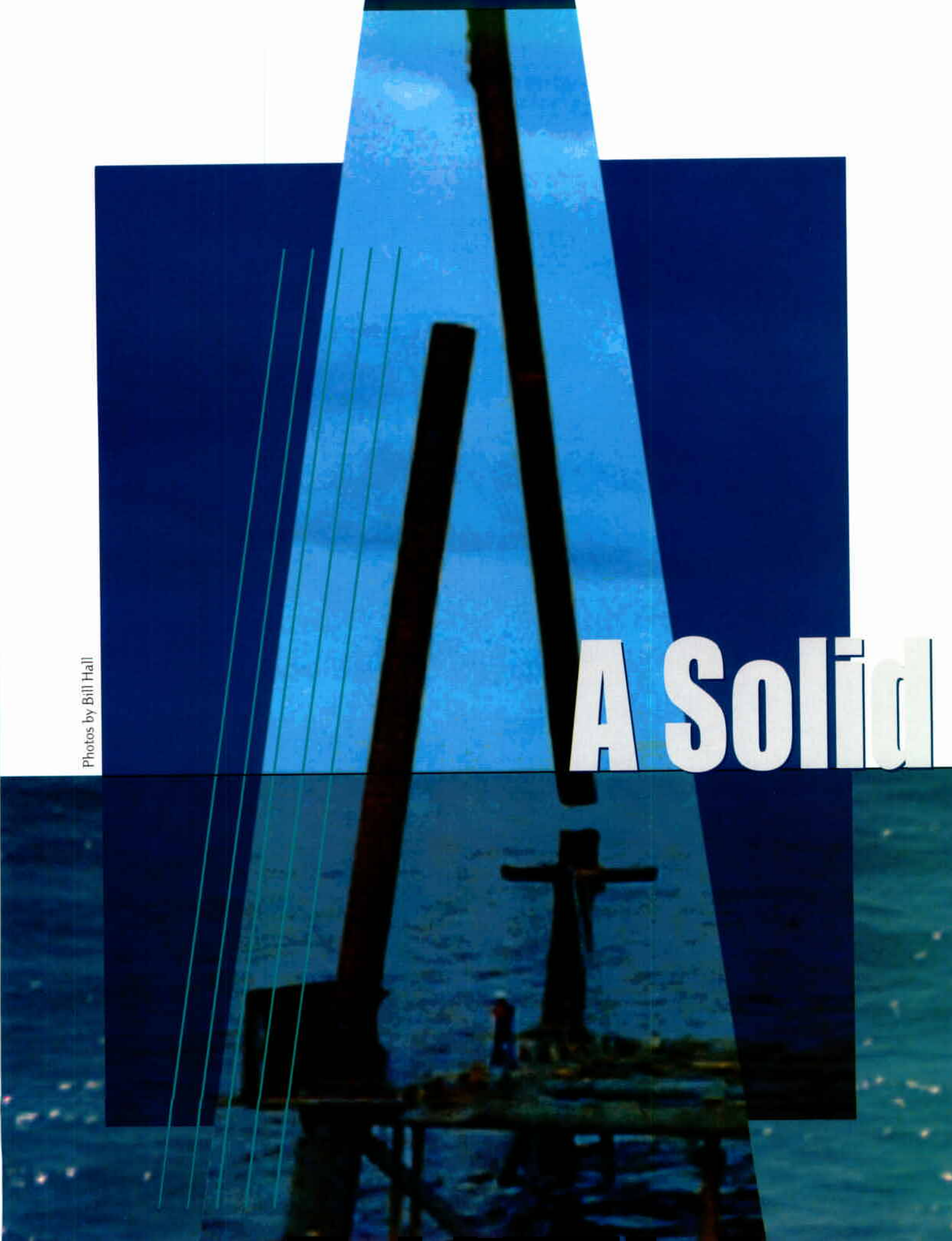
Journal


2


16


24


30

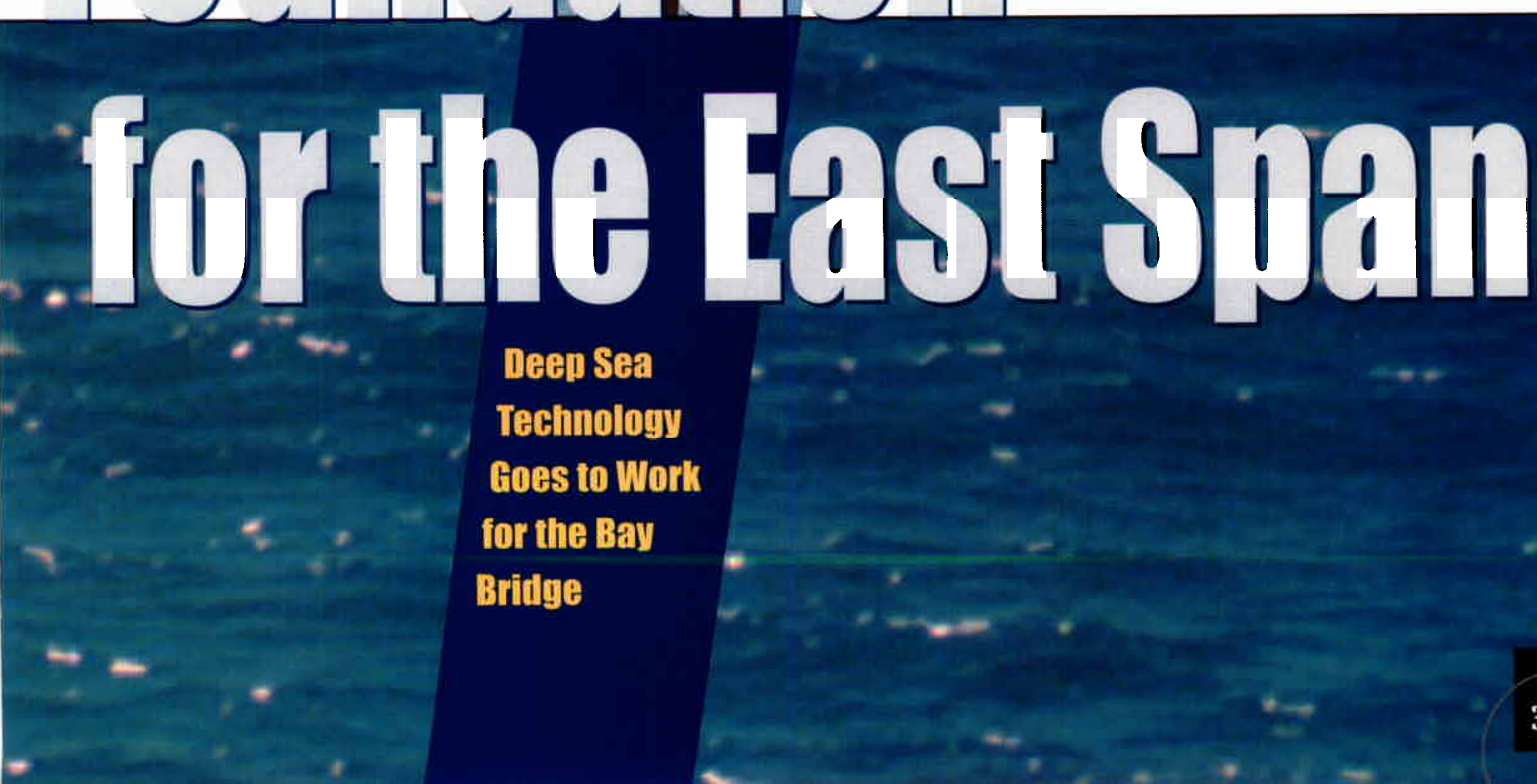


A Solid

Photos by Bill Hall

Foundation for the East Span

Deep Sea Technology Goes to Work for the Bay Bridge



Dr. Brian Maroney stands in his cluttered office at Sacramento's Farmer's Market # 1, feet together. His body waves like a reed in the wind. "This is what happens with vertical piles under certain conditions in an earthquake," he says. Maroney spreads his feet apart. "Now, look what happens. I have a great deal more structural rigidity."

Maroney is demonstrating the difference between vertical piles and the "battered," or inclined, piles being tested in a $7.3 million demonstration project for piles to be used in the replacement of the eastern span of the San Francisco-Oakland Bay Bridge. "It's about setting up conditions to make less material do more for you as an engineer," says Maroney, a Supervising Structural Engineer.

Maroney heads a team that is developing the seismic treatment for the bridge replacement, which, at an estimated cost of $1.5 billion, is likely to be the most costly project ever undertaken by Caltrans.

"The concept came up when we were still anticipating a retrofit of the existing east span," Maroney says. "We were working with Chris Traina (a Caltrans Bridge Cost Estimating Engineer) on ways to limit the permanent displacements of the caissons that were part of the retrofit project.

"We were offering different ways to reduce the displacements and Chris would offer guidance as to how expensive each strategy would likely be. This is a good example of how work on the retrofit of the east spans allowed us to choose new bridge structure types wisely, which enhanced the performance. When it became clear a replacement strategy for the east spans was a better financial and engineering alternative, we asked the design team to evaluate the use of battered piles to improve the design of the replacement, and they did a good job."

Offshore oil drilling companies had used battered piles successfully for two decades, but they were used only occasionally and under special conditions for bridges. "Battered piles had a reputation for performing poorly in seismic events," says Maroney. "But when the project team analyzed those failures, what we saw was that they hadn't been designed for seismic events. If we could prepare a design that took all the factors into account, battered piles might have advantages, especially in the muds that underlie the San Francisco Bay."

The project team has been meticulous in its study of the materials in which they will have to work, doing $15 million of geotechnical study while developing the seismic strategy for the bridge. This preliminary work is expected to pay off in a clear knowledge of the properties of the materials into which the piles will be embedded. "The Lower Alameda Formation, a mixture of sand and clay, not strictly classified as rock, is about as close to rock as you can get," Maroney says.

Earthquakes near the San Francisco Bay typically strike with great intensity because the layers of mud underlying the bay amplify the force of the seismic event to any structures standing on top of them.

Earthquake ground motions near the San Francisco Bay typically strike with great intensity because the layers of soft mud amplify the motions of the seismic event to any structures on them. Studies of earthquakes in other settings had driven an observation that stiffer structures would perform better in a severe earthquake in such an environment. Ancient stone churches of a very rigid construction, for instance, survived the 1985 Mexico City earthquake, when more modern but less rigid structures did not perform as well.

"This is an instance of wisely avoiding resonance," says Maroney. Seismic resonance is the condition of earthquake motions being of very similar frequency to a structure's natural frequency, which causes the structure's response to grow exponentially.

Battered piles could provide a number of advantages. The retrofit project had offered evidence that vertical pile groups were costly and not efficient because of a phenomenon called pile shadowing. If piles are too closely spaced, the soil between them is overloaded and becomes less effective. This can set up a condition in which two piles must be placed in the ground to provide the strength and stiffness of one.

If the spacing of the vertical piles is simply increased, the pile group efficiency will increase. But such a design requires a larger and more costly pilecap that would generate larger seismic loads, because its larger mass negates some of the effectiveness of the pile group. The battered pile foundations benefit twice. By being anchored in stronger materials below the bay muds at a depth at which the presence of the batter has spread the pile group, the shadowing effect is eliminated.

The battered pile foundations also benefit from the deeper point of effective fixity, since seismic motions tend to increase as the waves propagate to the surface from the bedrock below.

The battered piles looked good on paper, but their benefits came at a price. The design of the smaller pilecap becomes more complicated. The design team must design for three shears and three moments, which are generated from the enhanced frame action of the battered piles and the pilecap, at the pile-to-pilecap connection.

Maroney says, "This is quite achievable and well worth the benefits realized along the length of the new spans. We have an outstanding geology and design team that is up to the task and we know how to do it."

The final hurdle in realizing the success of the battered piles is to work with Caltrans' construction partners to demonstrate that this type of construction, which is new to us, can be completed without unknown and unnecessary complications," says Maroney. Hence, the demonstration project. The demonstration consists of driving three piles at two sites near the existing East Span. The sites are in open water and fall within the Caltrans 150m maintenance area extending north and south from the centerline of the existing bridge. Caltrans identified the test sites based on their location within the east span project area, soil conditions, and on additional criteria including adequate water depth and minimal potential conflict with other marine vessels or future bridge construction operations.

The demonstration project presents mammoth problems. The 2.5 m (7 1/2 ft.) diameter steel piles, of the type proposed for the main span and skyway, must be long enough – 100 m – to extend through the soft bay muds into the dense marine sands of the Alameda Formation. Stand a football field on end and you've got an idea of their length.

Essentially hollow steel tubes, the piles will be driven into the rigid materials below the bay. The actual bridge piles will be filled with reinforced concrete to provide additional structural rigidity and strength for the bridge foundation.

The test will be conducted from a floating platform similar to those used by oil companies to drive piles for deep sea drill rigs. The contractor will have to devise a template to keep the massive pile within 200 mm of the precise 6:1 incline, then control its "run" as it drives through the top layers of soft mud. That run could be as long as 30 m, and the first application of the 1700 Kj hammer could send it another 10 m into the mud.

"It is one thing for us to be confident of the technology but, in order for our contractors to bid prudently, they have to be confident of it, too," says Maroney. "So we do a demonstration project and let the contractors watch." The pile installation demonstration project will provide Caltrans and its contractors with critical information to plan and finalize construction techniques.

The piles will be monitored throughout the driving process to determine the amount of run and the resistance encountered with each application of the hammer. Samples of the materials encountered will be tested to assure that they are consistent with results already developed through earlier geotechnical testing.

The contractor will have a 48-hour window in which to weld the pile sections together, reposition the template and hammer and complete ultrasound testing of the welds. If they are allowed to rest for longer than 48 hours it is likely there will be difficulties in resuming the driving. Testing of the welds will be done by ultrasound, bouncing sound waves through the welds to find any imperfections.

"When you drive a pile into the soil, you are failing the soil," Maroney says. "With the Lower Alameda Foundation, our tests show that the material will be initially strong enough to support the bridge structure, but it will regain its strength over time. Over a period of about a year, it will become very strong and we will have more than adequate rigidity and strength for the new bridge."

The demonstration will also help determine whether or not to place the piles as a single unit, or place them in two or more pieces and weld them together. If they are placed in pieces, the demonstration will provide information about the quality of the welds – an essential in producing the quality steel pile foundation needed.

Mansion and Dutra, a Bay Area joint venture, both with extensive experience in building structures in marine environments, was awarded the $7.3 million contract to perform the demonstration project on July 14, 2000. The joint venture will fabricate a 25 m-tall (80 ft.), template to hold the piles in place, incorporate a 1700 Kj hammer, and place it on eight temporary piles to be driven into the Bay mud at two separate sites. The piles will be placed in three or four sections and welded in place.

The demonstration project presents mammoth problems. The 40 to 70 mm thick, 2.5 m-diameter steel piles, of the type proposed for the main span and skyway, must be long enough – 100 m – to extend through the soft bay muds into the dense marine sands of the Alameda Formation.

Caltrans' Construction Engineer for the demonstration is Mark Woods, a Range D with eight years experience in the Caltrans Structures division on a variety of projects. Aided by a staff of four assistants and plenty of help from various engineering divisions throughout Caltrans, he will oversee the 35-day project.

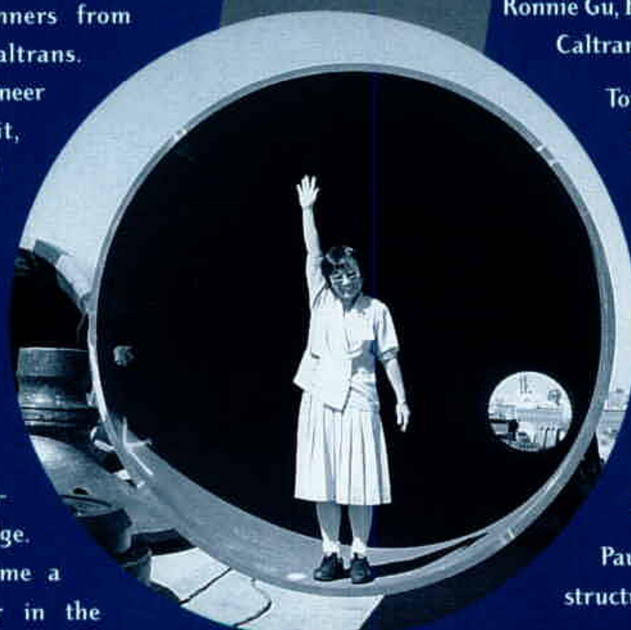
After placement, the piles and surrounding materials will be monitored for at least a year. They may be used during construction of the replacement bridge, then cut off at the mud line, having done their job.

"We are demonstrating to our partners that these piles can be placed efficiently," Maroney says. "We believe this demonstration project will forestall unnecessary increases in contractors' bids to account for unknowns concerning the battered piles. We intend to remove those unknowns in order to get lower bids from our contractors."

A Major Team Effort

If, someday, someone were to give an awards banquet similar to the Academy Awards, and they gave an award to the team that developed the battered pile concept for the San Francisco-Oakland Bay Bridge replacement project, half the audience would be trooping to the stage to accept.

Unique and difficult projects don't get done by a single person. The Pile Demonstration Project has been supported by a large team of geologists, engineers and environmental planners from inside and outside Caltrans. Senior Transportation Engineer Pochana Chongchaikit, (shown inside pile, inset) District Project Engineer Sharon Naramore and Toll Bridge Construction Engineer Mark Woods have provided leadership to the team.



The concept started with the cost analysis of retrofitting the existing bridge. Chris Traina, at that time a Senior Bridge Engineer in the Structures Cost Estimating Section, worked with bridge designers Eric Zechlin and Eric Moran on the earliest concepts of using battered piles. Before the concept was advanced to project status, Caltrans design engineers reviewed the concept for constructability with Gerwick, the 80-year-old former president of Ben C. Gerwick Construction and a professor at U. C. Berkeley.

The team also included:

John Thorne, and Reed Buell, Caltrans geologists

Ronnie Gu, Bob Price and Saba Mohan, Caltrans geotechnical engineers

Tony Dover, Bob Stevens and Po Lam from the Fugro-Earth Mechanics joint venture

Jeff Aldridge, CH2Mhill specifications engineer as a subconsultant to Parsons Brinkerhoff, Jerry Houlihan, T. Y. Lin-Moffitt and Nichols joint venture structure designer

Paul Bahga, Caltrans structure designer,

Marilee Mortonson, Caltrans environmental planner

Joy Mashaal, Woodward-Clyde-URS Griener Consultants wildlife biologist

Nick Fioentinos, Caltrans Right of Way agent

"These people and many others have worked so hard that sometimes I'm ashamed to be asking so much of them," says Brian Moroney. "They are saving the taxpayers a tremendous amount of money and they're going to give them an outstanding bridge."

Maria Contreras-Sweet
Secretary of the Business,
Transportation and Housing Agency

Gray Davis
Governor of California

Jeff Morales
Director of the California
Department of Transportation (Caltrans)